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Canadian Science Advisory Secretariat
Science Advisory Report 2007/009

ASSESSMENT OF COD IN THE SOUTHERN GULF OF ST. LAWRENCE (NAFO DIV. 4T)

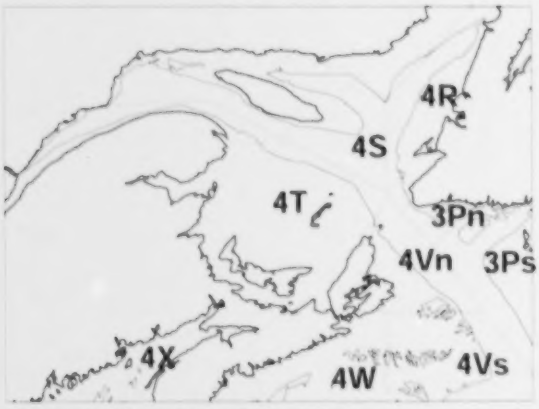

Figure 1: Map of the Gulf of St. Lawrence showing NAFO divisions.

Context

Southern Gulf cod have been exploited commercially since at least the 16th century. Landings varied between 20,000 and 40,000 t annually between 1917 and 1940, and then began to increase to a peak of over 100,000 t in 1958. The fishery was primarily prosecuted with hook and line until the late 1940s, when a ban on otter trawling was lifted. Landings remained relatively high in the 1960s and early 1970s, in the range of 60,000 t. TACs were first imposed in 1974, and these became restrictive as the stock declined in the mid-1970s. The stock recovered somewhat and landings returned to the 60,000 t range during the 1980s. During the 1980s, the fixed gear fishery declined drastically, and the fishery was mainly prosecuted by mobile gear until it was closed in September 1993, due to low abundance. A 3,000 t index fishery was allowed in 1998; catches were 2700 t. A TAC of 6,000 t was in effect from 1999 to 2002. Larger mesh sizes were used in the mobile gear fishery after the re-opening. The directed fishery was closed again in 2003 due to a lack of recovery but re-opened at a TAC of 3,000 t in 2004 and 4, 000 t in 2005 and 2006. The management year for the fishery now runs from May 15 of the current year to May 14 of the following year. The management unit for this stock includes all of 4T and catches in 4Vn during November-April. In some years, catches in 4Vs in January-April are attributed to this stock (Fig.1). Assessments of this stock are generally required on an annual basis and the results form part of the information base used to establish the TAC.

SUMMARY

- In 2006-2007, the TAC was 4,000 t. As of December 31, 2006, 2,750 t had been landed. An additional 143 t were landed in 4Vn in January 2007.
- All the abundance indices indicate that this stock is at or near a record-low level and is declining.
- Spawning stock biomass is estimated to be at the lowest level observed in the 58-year record. The current estimate of spawning stock biomass is 48,000 – 50,000 t (depending

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on the population model used) at the beginning of 2007, a 2-8% decline below the 2006 biomass.

- Spawning stock biomass is estimated to be well below the limit reference point for this stock (80,000 t). Below the limit reference point, a stock is considered to have suffered serious harm because the probability of poor recruitment is high.
- Recruitment of year-classes produced since the late 1980s has been significantly below the long–term average. The 2003 year-class is estimated to be very low, less than half the strength of any other recent year-class. The first estimate of the 2004 year-class is also relatively low.
- Natural mortality remains high (0.4 or higher), about five to six times the level of fishing mortality in 2006 (0.07-0.08). Predation by seals is considered to be a significant component of natural mortality.
- Even with no catch in 2007, spawning stock biomass is almost certain to decline, with a 78% probability of a decline of 10% or more based on the recommended population model and a 63% probability of a decline of 5% or more based on an alternate model.
- At the current high natural mortality rates and low growth rates, rebuilding of spawning stock biomass will require improved recruitment and low catches, and is expected to be very slow.
- Given the current stock status, the application of the precautionary approach would require that removals in 2007 be set at the lowest possible level.

BACKGROUND

Species Biology

Atlantic cod (*Gadus morhua*) is a demersal fish species which occurs on both sides of the North Atlantic. Southern Gulf of St. Lawrence cod are relatively long lived, and may reach ages of 20 or more when mortality is low. Cod from the southern Gulf of St. Lawrence are relatively slow growing compared to other cod populations. Individual fish growth is estimated to have declined in the late 1970s and has remained low since. They begin to reach commercial size (43 cm) at about age 5, and are fully available to the commercial fishery by age 8. They start to mature at a size below the commercial size of 43 cm (ages 4-5) and by age 7 most fish in the population are sexually mature. It is estimated that the natural mortality of southern Gulf of St. Lawrence cod increased in the 1980s.

Southern Gulf cod are highly migratory. Spawning occurs in the Shediac Valley and around the Magdalen Islands from late April to early July. During the summer, the cod are widely distributed while they feed heavily on krill, shrimp, and small fish, primarily herring, American plaice, and capelin. The fall migration begins in late October and cod become concentrated off western Cape Breton in November as they move into 4Vn. The stock overwinters in 4Vn and northern 4Vs, along the edge of the Laurentian Channel. The return migration usually begins in mid-April, although this can be delayed by the late breakup of winter ice.

Fishery

A TAC of 4,000 t was in place for 2006-2007. This included an allowance of 200 t for sentinel and scientific surveys. Cod were caught in cod-directed fisheries and as by-catch in fisheries directed at other species, mainly flatfish. Directed fisheries for cod were closed before June 24, 2006. By-catch of cod in other fisheries was restricted to between 5 and 25% depending on the target species. As in the last few years, a recreational fishery for cod was prohibited.

Table 1: Landings and TACs (thousands of tonnes) for southern Gulf of St. Lawrence cod.

Year	Average 1981 - 1990	Average 1991 - 1995	Average[1] 1996 - 2001	2002	2003	2004	2005	2006[2]
Landings	60.8	19.7	4.0	5.1	0.3	2.3	2.8	2.8
TAC	57.5	20.8	3.6	6.0	0	3.0	4.0	4.0

1. Including the allowance of 3000 t for an index fishery in 1998.
2. Preliminary data up to December 31, 2006
(Note: starting in 1999, TAC for May 15 to May 14 of the following year.)

The total reported **landings** were 2,750 t in 2006 (Table 1, Fig. 2). Catches in the cod-directed and by-catch fisheries amounted to 2,664 t. Catch reporting in the commercial fishery is considered reliable. The TAC was not reached because little effort was directed for the 4Vn allocation and some other allocations were not reached (e.g. French reserve, sentinel allocation, fixed gear allocations). An additional 143 t were landed in 4Vn in January 2007. Catches from January 1 to May 14, 2007, are expected to be about 5% of landings in 2006. Sentinel surveys that are used to obtain additional indices of abundance of the stock caught 86 t.

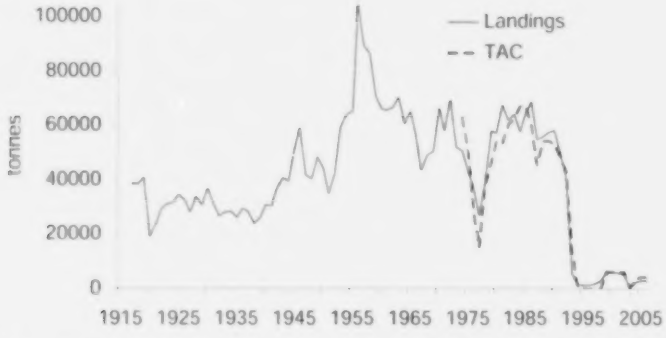

Figure 2: Landings and TAC (t) for the southern Gulf of St. Lawrence cod stock.

The dominant age-groups in 2006 landings were ages five to seven. The **average weights** at age of cod in the catch and in the annual research vessel survey remained low in 2006 relative to the period before 1980 (Fig. 3).

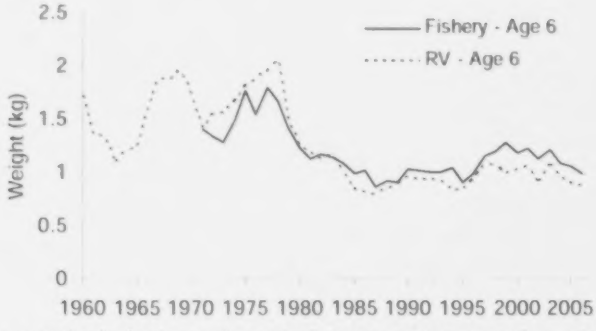

Figure 3: Average weight (kg) of age 6 cod in fishery catches and from the research survey.

ASSESSMENT

Stock Trends and Current Status

The information used in this assessment includes the annual research vessel survey (1971-2002, 2004-2006), landings data from 1917-2006, commercial catch information from 1950-2006, sentinel survey data from 1995-2006, otter trawl catch rate data from 1982-1993, and the views of industry expressed in the annual telephone survey from 1997-2002 and 2004-2006.

The **views of fishers** on the state of the resource were obtained through a telephone survey of active cod fishers in 2006. Of the 138 fishers interviewed who indicated that cod was their first priority, 51% felt that the status of the stock was lower or much lower when compared to 2005, while 18% considered the 2006 cod abundance to be higher (17%) or much higher (1%) than in 2005. Compared to all years fished, 57% thought that cod abundance was lower or much lower in 2006, 22% thought that it was about the same, 10% thought that it was higher or much higher, and the remainder had no opinion. In 2005, interviewed fishers were less positive about stock abundance than in previous years; in 2006, the average opinion of interviewed fishers was for the first time negative (Fig. 4).

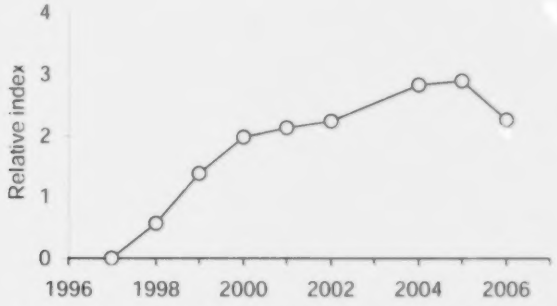

Figure 4: Relative index of cod abundance based on the opinion of fishers who indicated cod as first priority.

The **annual research vessel (RV) survey** has been conducted in September since 1971. The survey index indicates that the abundance of cod was low in the early to mid-1970s then increased to the early 1980s. Abundance was high until the late 1980s but declined rapidly to low levels by 1992. With the closure of the fishery in 1993, the decline was arrested but the abundance index has remained low.

There have been changes in the research vessels used in recent years for the survey. In 2003, the *CCGS Alfred Needler* was replaced by the *CCGS Wilfred Templeman*. Because no comparative fishing experiments were conducted, the results in 2003 were not used here as an indicator of stock status. Starting in 2004, the *CCGS Teleost* was employed for the survey using the same Atlantic Western IIA trawl as used previously. In both 2004 and 2005, comparative fishing experiments were conducted between the *CCGS Teleost* and the *CCGS Alfred Needler* while conducting the annual survey. The analysis of paired fishing sets by the two vessels indicated no significant difference in catchability between these two vessels for cod in the southern Gulf. Data from both vessels have been used to calculate the abundance estimates for 2004 and 2005. In 2006, fishing was by the *CCGS Teleost*.

The 2005 estimates of abundance and biomass were the lowest seen in the time series. The 2006 estimates remained near these record-low values (Fig. 5).

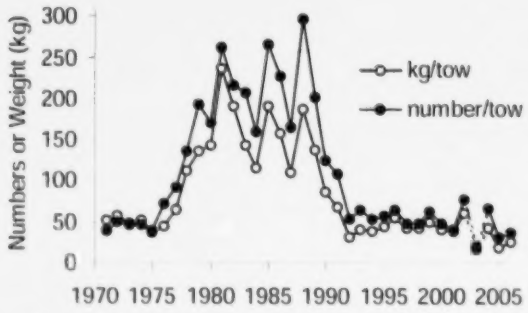

Figure 5: September research survey abundance indices for cod 2 years and older (2003 is not considered a comparable indicator).

In 2004, the abundance of cod aged two and three years was significantly higher than that observed in the surveys conducted in the several years prior to 2003. These fish are the 2001 and 2002 year-classes, and they accounted for almost half of the estimated abundance in the 2006 survey. Abundance of the 2003 year class appeared to be very low in both the 2005 and 2006 surveys.

The geographic distribution of cod in the 2006 survey was generally consistent with that observed in recent years. Highest concentrations were found in the Shediac Valley, the north coast of PEI, and off northwestern Cape Breton (Fig. 6).

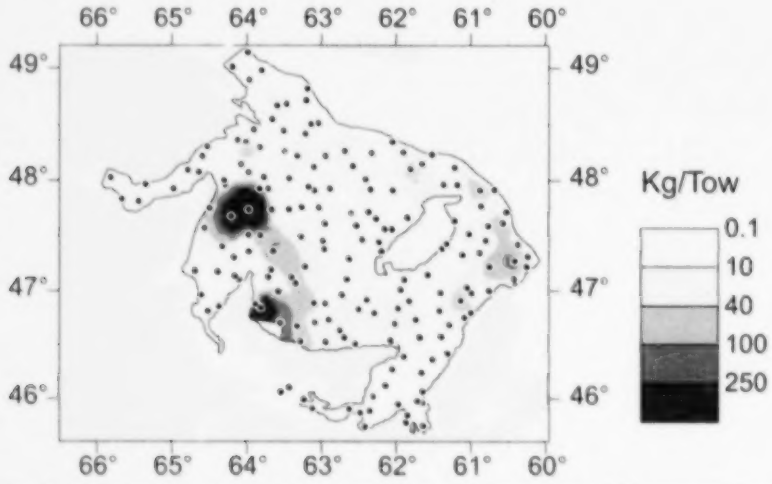

Figure 6: Distribution of cod (kg per set) in the September 2006 research survey.

The sentinel survey program was continued in 2006. Two types of surveys are conducted: a trawl survey in August and a sentinel longline survey from July to November. The synoptic **sentinel trawl survey** was started in 2003. Estimates of abundance and biomass from the trawl survey continued to decline in 2006, reaching the lowest levels in the 4-year time series (Fig. 7).

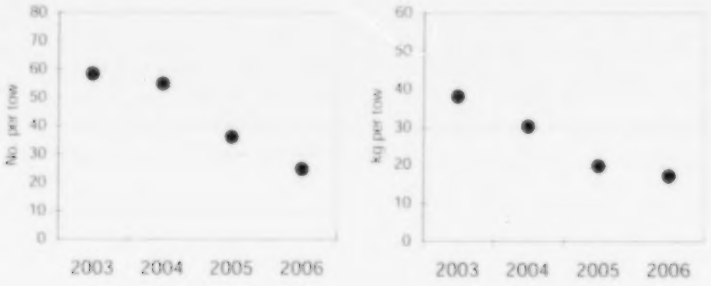

Figure 7: August sentinel trawl survey indices. Vertical bars indicate approximate 95% confidence intervals.

The length frequency distribution in the sentinel trawl survey was similar to that obtained in the September research vessel survey when accounting for within-year growth (Fig. 8). Fewer fish less than 20 cm were caught in the sentinel survey owing to the larger mesh size of the liner used in the sentinel trawl. Ages 4 to 6 were important in the age composition of cod caught in both the sentinel trawl and RV surveys (Fig. 9).

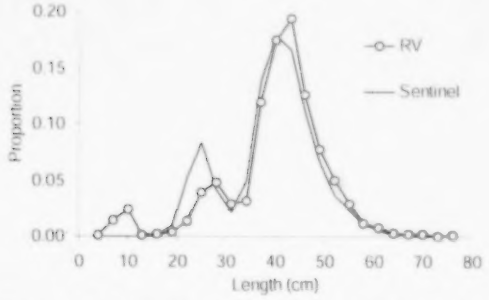

Figure 8: Length frequency distribution of cod caught in the August 2006 sentinel trawl survey and the September 2006 research vessel survey.

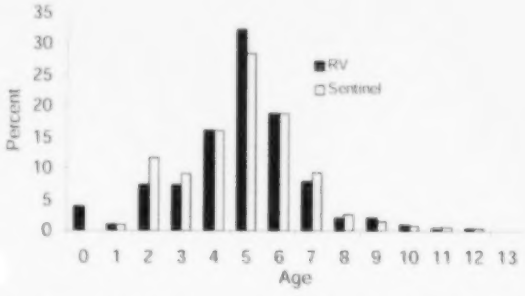

Figure 9: Age composition of cod caught in the August 2006 sentinel trawl survey and the September 2006 research vessel survey.

Geographic distribution of cod in the sentinel trawl survey was similar to that observed in the research vessel survey, with highest cod densities located in the Shediac Valley and in the area between the Magdalen Islands and Cape Breton (Fig. 10). Relative density was lower north of PEI in the sentinel trawl survey than in the research vessel survey.

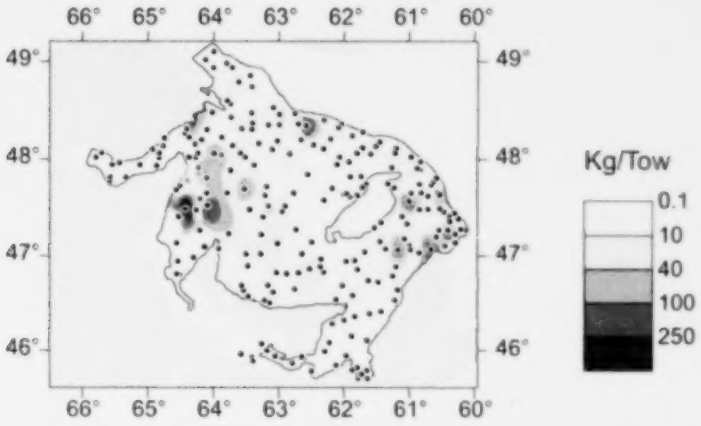

Figure 10 : Distribution of cod (kg per set) in the August 2006 sentinel trawl survey.

The **sentinel longline survey** resulted in a catch of 81 t. Eighteen vessels fished at 38 reference sites. Standardized catch rates decreased in 2005 and again in 2006 (Fig. 11). The 2006 value is the lowest in the time series and is significantly lower than the values prior to 2005.

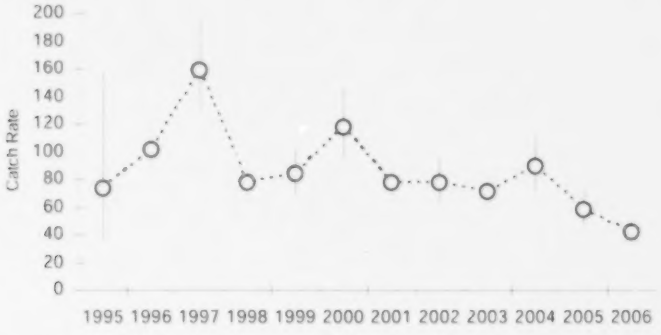

Figure 11: Longline sentinel catch rate index. Vertical bars indicate approximate 95% confidence intervals.

In summary, all the abundance indices indicate that the stock is at or near a record-low level and is declining.

Previous work has indicated an increase in the **natural mortality** rate (*M*) of this cod stock. This would include unaccounted mortalities due to factors such as poor environmental conditions, predation, unreported catches and changes in life history characteristics. Estimates of natural mortality from population analyses indicated that *M* increased in the 1980s and has not declined appreciably since the late 1980s. Total mortality estimates (*Z*) from survey data also suggest that *M* was near 0.4 or higher during the moratorium in 1994-1997. Recent estimates of total mortality based on the RV and sentinel trawl survey data are very high, suggesting that *M* may now be increasing to values above 0.4.

The contribution of each of the potential causes of the recent high estimates of *M* is undetermined. Consumption estimates of cod by grey and harp seals in 2000 for this stock range from 19,000 to 39,000 t (all ages) depending on diet assumptions. The higher estimates were produced using diet compositions from outside the stock area. Cod consumption by grey seals is estimated to exceed that by harp seals in the southern Gulf. Although diet samples

suggest that most cod consumed by seals appear to be less than 35 cm in length, diet analyses cannot account for cod that may be killed but not consumed totally (heads are not eaten). Changes in natural mortality estimates for cod are consistent with trends in grey seal abundance in the southern Gulf of St. Lawrence.

Population models used in recent assessments of this stock have assumed that *M* was 0.2 up to 1985 and 0.4 since 1986. Following the recommendation of a recent review of the evidence on levels of *M* in the Gulf of St. Lawrence cod stocks (DFO 2007), a revised model was used in this assessment. *M* was fixed at 0.2 in 1971-1979 and at 0.4 in 1994-1997, and estimated in other periods. These models are referred to here as Models 1 and 2, respectively. Model 2 estimated that *M* increased in the 1980s, and was near 0.4 in 1998-2001 and 0.5 in 2002-2006 (Fig. 12).

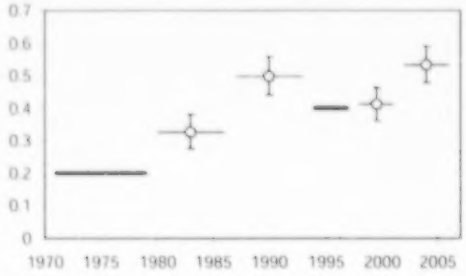

Figure 12: Natural mortality (M) in population Model 2. Heavy lines are assumed values and circles values estimated by the model with their 95% confidence intervals.

Because the estimated *M* in the revised model was higher than the value assumed in the previous model in some periods, abundance and biomass was estimated to have been higher in the 1980s in the revised model. However, trends in abundance and biomass were similar between the two models. Total (ages 3 and older) and spawning stock biomass were high in the 1950s, but declined throughout the 1960s and reached a minimum in the mid-1970s (Fig. 13). Spawning biomass increased sharply with the recruitment of strong year-classes (1974-75, 1979-80), but then declined rapidly, reaching a low in 1993 (Fig. 13). Spawning stock biomass has been low since the early 1990s and has declined since 2002. The estimate of spawning stock biomass at the beginning of 2007 is 48,000 t based on Model 2.

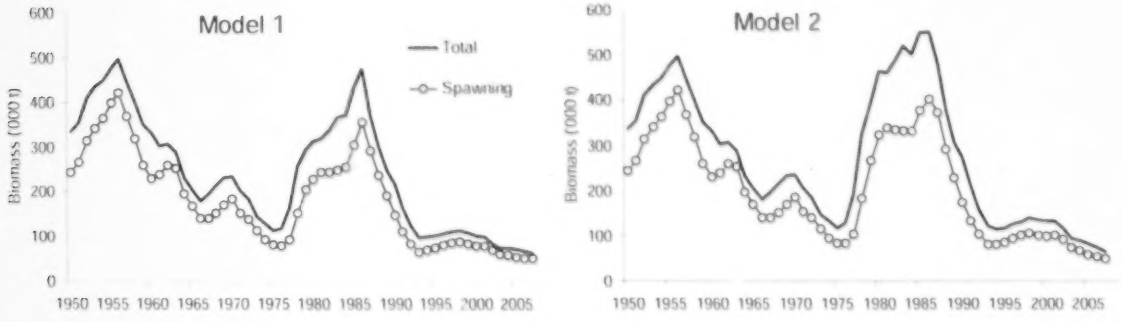

Figure 13: Total and spawning stock biomass estimates derived from population models for cod in the southern Gulf of St. Lawrence.

The trend in total abundance (Fig. 14) is similar to that of biomass (Fig. 13), except that abundance was greater in the 1980s than the 1950 whereas biomass was similar between the two periods. This difference reflects the younger age composition and lower weights at age in the 1980s than in the 1950s. Abundance was stable at a low level in the mid to late 1990s, but declined further in the early 2000s. Abundance increased somewhat in 2004 and 2005 because the 2001 and 2002 year-classes are more abundant than those of the preceding several years. Abundance declined after 2005 because of the very weak 2003 year-class.

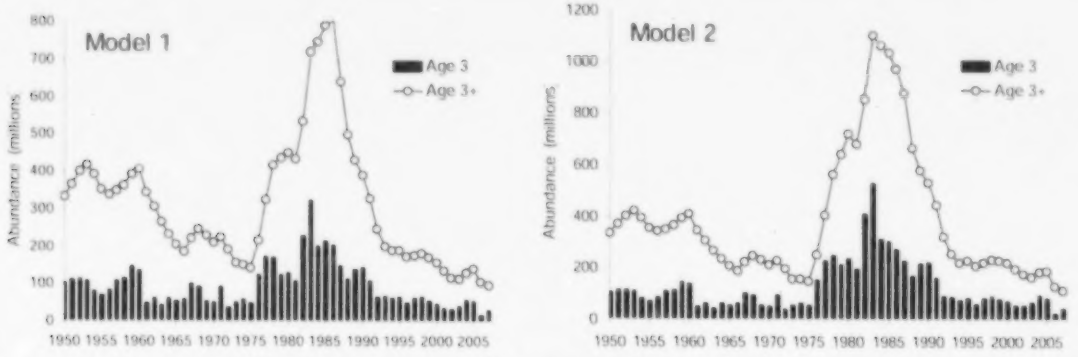

Figure 14: Population abundance (ages 3+) and recruitment estimates for southern Gulf of St. Lawrence cod.

Recruitment of year-classes produced since the late 1980s has been significantly below the long–term average. The 2001 and the 2002 year-class are estimated to be slightly more abundant than the very weak year-classes preceding them. However, the estimate of the 2003 year-class is very low, less than half the strength of any of the other low year-classes recently observed. The first estimate of the 2004 year-class is also relatively low.

Analyses indicate that the high production of recruits from the mid-1970s to early 1980s may have resulted from the low abundance of pelagic fish species (herring and mackerel). Herring and mackerel feed on small prey including the early life stages of cod (eggs and larvae). Herring biomass in the southern Gulf has been at a relatively high level since the mid-1980s and has been increasing since the mid-1990s.

The exploitation rate of commercial fisheries on southern Gulf cod increased from the early 1950s to the mid-1970s, with the exception of a high value in 1959 (Fig. 15). There was a decrease following the extension of fisheries jurisdiction in 1977. Exploitation rate increased sharply in the late 1980s, peaking near 60% in 1992. Fishing effort was reduced markedly in 1993 with the closure of the directed fishery. Exploitation rates were 1-2% during the moratorium. In 2006, the exploitation rate was estimated at about 6-7% (F=0.07-0.08).

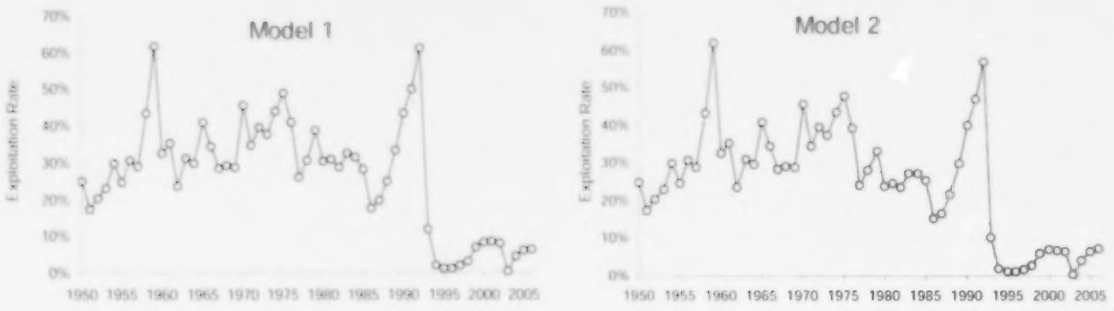

Figure 15: Exploitation rate (ages 7+) for southern Gulf of St. Lawrence cod.

Sources of Uncertainty

The level of natural mortality in recent years remains a source of uncertainty in the assessment. Predation by seals is considered to be a significant component of natural mortality and analyses suggest that changes in natural mortality are consistent with grey seal abundance trends. Recent analyses indicate that seal predation is higher than previously estimated; however, there is considerable uncertainty about seal diets in the southern Gulf. Diet analyses rely on the presence of hard parts from prey species in seal stomachs. Conclusions about diet composition would be affected if seals tend not to eat the heads of larger cod.

The lack of survey data for 2003 introduces uncertainty in recent abundance trends. The estimates of recent year-classes (2003 and 2004) are uncertain as they are based on few observations. However, these year-classes will not contribute significantly to the fishery or the spawning biomass until 2008 and 2009.

CONCLUSION AND ADVICE

The productivity of the stock has been low for more than a decade because of poor growth and high natural mortality. The estimates of the 1998, 1999 and 2000 year-classes are amongst the lowest on record. While the estimates of the 2001 and 2002 year-classes are slightly higher, the 2003 year-class is estimated to be much weaker than any other year-class observed, and the first estimate of the 2004 year-class is also low. Natural mortality remains high and may be increasing to even higher levels. The outlook for the stock is thus more pessimistic than in the previous assessment and further declines are expected in the short term.

Projections based on the point estimates of stock size from Model 2 predict that the spawning biomass will decrease by about 12% over the next year even if there is no catch in 2007. Catches of 3,000 t (about the level of catch in 2006) in 2007 would result in a 16% decline in spawning stock biomass. Projections based on the population model used in the last assessment (model 1) are slightly more optimistic, indicating a 6% decline with no catch and a 10% decline with a catch of 3,000 t in 2007.

It is also possible to estimate the uncertainties regarding stock size (and natural mortality, if it is estimated in the population model) and then use these in **risk analyses**. These risk analyses include uncertainties in the population estimates but not those associated with weight at age and partial recruitment (or natural mortality if its value is assumed). It should be noted that risk was calculated for the calendar year, whereas TACs for this stock are set for the period 15 May to 14 May.

Analyses based on Model 2 indicate that, even with no catch in 2007, spawning stock biomass is almost certain to decline by 5%, with a 78% probability of a decline of 10% or more. With a catch of 3000 t, the probability of a 10% decline is 97% and the probability of a 15% decline is 68%. Model 1 is only slightly more optimistic, indicating that even with no catch, spawning stock biomass is almost certain to decline in 2007, with a 63% probability of a decline of 5% or more. With a catch of 3000 t, Model 1 indicates a 98% probability of a 5% decline and a 49% probability of a 10% decline.

The estimated conservation reference limit point for this stock is 80,000 t. This is the stock level below which productivity is sufficiently impaired to cause serious harm to the resource. When a stock is below this level, in order to be compliant with the Precautionary Approach, fishery management actions must promote stock growth and removals by all human sources must be kept to the lowest possible level (DFO, 2006a). The current estimate of spawning stock biomass of southern Gulf cod (48,000 t) is the lowest observed and is well below the limit reference point. The probability that the stock will remain below the limit reference point in 2008 is 100% according to both models.

This stock currently has little or no surplus production. A fishery on this stock is not sustainable at its current level of productivity. Given the status of the stock relative to the limit reference point and the lack of improvement foreseen for the next year, it would be advisable to limit catches to the lowest level possible in order to minimize expected declines and in order to be compliant with the Precautionary Approach. For this stock, a catch of 300 t is considered to be the lowest possible level (DFO, 2006b).

At the current high natural mortality rates and low growth rates, rebuilding of spawning stock biomass will require improved recruitment and low catches. The chance of substantially improved recruitment may be low given the high pelagic biomass and low cod spawning stock biomass. If rebuilding does occur, it is likely to be very slow. If current conditions persist, very little increase in spawning biomass can be expected and further declines are likely.

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